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NUMERICAL ANALYSIS OF SECONDARY FLOWS AROUND AN OSCILLATING CYLINDER

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Abstract: This paper considers methods for controlling secondary flows near an oscillating circular cylinder by changing two process control parameters: the dimensionless amplitude and the vibrational Reynolds number. A direct numerical modeling study is performed. It is shown that by varying the indicated parameters in a relatively small range, it is possible not only to intensify mass transfer processes, but also to change the direction of the main secondary flows.

Keywords: secondary steady flows, acoustic flows, flow regimes, Navier–Stokes equation, numerical simulation.

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INTRODUCTION

Oscillations of a body in a viscous fluid involve not only the formation of an unsteady boundary layer and vortices near the body, but also the occurrence of global steady flow, which causes motion of a significant mass of fluid around the body. This secondary flow is often used to control the transfer and mixing of fluids. The occurrence of such steady flows near obstacles in air under the influence of sound waves was first proved in [1, 2]. Therefore, they are often called acoustic streaming flows. In general, the presence of sound waves is a possible cause of such flows, which are nonlinear effects that arise in both compressible and incompressible fluids. In the case of interaction of oscillating flow with a solid body, their occurrence is due to viscous friction in the boundary layer near the body [3].

Accounting for secondary flows is important in the design of technical objects, because, e.g., the formation of such flows in the vicinity of marine engineering structures can lead to changes in the bottom relief beneath them [4]. In general, secondary flows have a significant influence on heat and mass transfer processes, and this is used in technological processes, e.g., ultrasonic cleaning of surfaces or rapid growth of crystals [5–7]. The possibility of using secondary flows to control the transfer and mixing of reagents in microfluidic devices is currently discussed [8, 9]. For small Reynolds number characteristic of these problems, the unsteady effects arising from the oscillatory motion of a body are significant only in its small neighborhood. In the outer region, fluid motion is completely determined by secondary flows, so that the problem of controlling such flows is important.

In this paper, we consider the evolution of secondary flows arising in a neighborhood of cylindrical bodies of circular shape harmonically oscillating in a viscous incompressible fluid with a change in the control parameters of the oscillation process. Symmetric secondary flows near cylindrical bodies in low-amplitude high-frequency oscillations have been studied most thoroughly [3, 10–12]. However, the results of studies [13–16] show that a symmetric structure of the flow is not the only possible. With an increase in the Reynolds number, new types of secondary flows arise, which are investigated in the present paper using direct numerical simulation. As a first step,

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